INFLUENCE OF THE TURBOGENERATOR DAMAGE ON THE RELIABILITY OF ITS OPERATION

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Introduction. Turbogenerators (TG) are one of the most common electric machines for electricity generation, widely used in thermal and nuclear power plants (NPP). The capacity of industrial TG reaches 800 – 1200 MW (Fig. 1). TG has round rotor, the so-called inductor, with a speed of 1500 or 3000 rpm. A steam turbine is attached to the rotor shaft, which steam is supplied under pressure. Air, hydrogen, or forced hydrogen-water cooling are used to cool the machine. TG rotor is usually mounted on two plain bearings [1]. Experience of this type of machine shows that the use of a rolling bearing at such speeds and prolonged operation is impractical and leads to its jamming or complete destruction, which requires emergency shutdown of the TG, and, as a consequence, significant economic losses due to power plant unit downtime. Therefore, research and analysis of the TG damage causes is topical scientific and technical task.

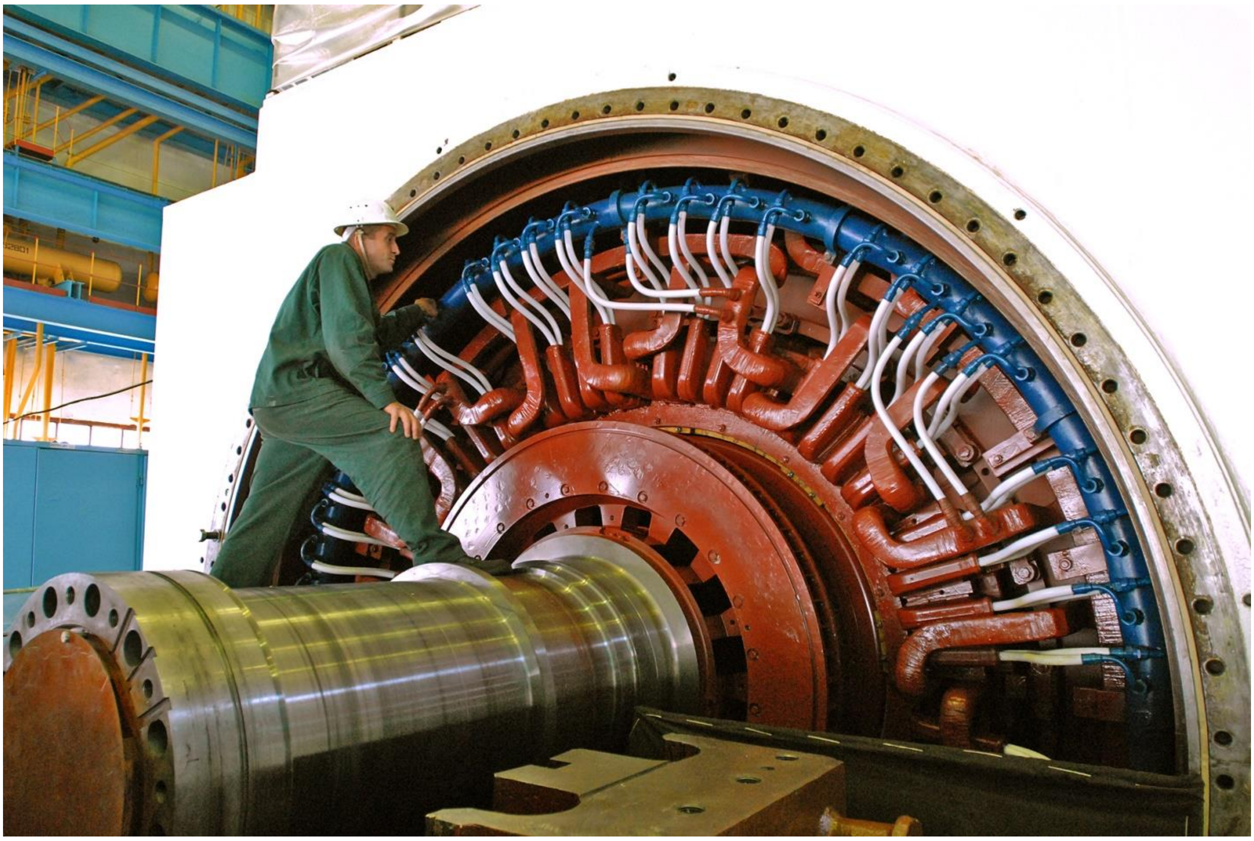

Figure 1 – Disassembled turbogenerator type TVV-1000-4 of Balakovo NPP [2]

The goal of the work. Analyze the damage impact to the turbogenerator on the reliability of its operation.

Materials and research results. Among the main damages of TG there are the following types.

Impaired circulation of the coolant. TGs of the TGV type with hydrogen cooling are produced with a capacity of 200 to 500 MW [3]. In particular, the rotor winding is usually cooled directly by hydrogen, and the stator is cooled by water or hydrogen through the channels of the stator winding or magnetic circuit, and the stator has a welded shell, which is sealed and can withstand high pressure inside the TG. When the coolant circulation in the stator winding rods decreases or stops, as well as when the hydrogen pressure in the housing decreases, the cooling deteriorates and, as a result, certain areas of increased heating are formed, which negatively affect the technical condition and operation of the machine as a whole. Increasing the local heating of the machine has a negative effect on the stator and rotor windings. The first sign of such phenomena is the operation of temperature sensors, as a result of which service personnel decides to reduce the output power of the TG or even stop it.

In 2009, at the Sultan Ismail power plant located in Terengganu in eastern Malaysia, a 124 MVA Toshiba generator, which was commissioned in 1984, failed. In particular, the loss of cooling water led to overheating of the generator, which caused the melting of the soldered joints of the stator windings (Fig. 2). These electrical connections in the stator winding allow current to flow from one stator rod to another. Overheating caused leakage of solder from the joints, interruption of current flow, melting of copper from the stator conductors, damage of the stator bus insulation. The generator was turned off due to the operation of automation. The most negative phenomenon for the turbogenerator and the power plant unit as a whole is the depressurization of the cooling system, including stator winding, which can lead to hydrogen detonation and, as a consequence, to the destruction of the power plant unit [5].

Figure 2 – Damage of the front part Toshiba TG stator winding insulation with a capacity of 124 MVA [4]

Damages of the stator and rotor windings insulation. Good insulation quality is one of the main prerequisites for proper operation and high performance of generators. Local "hot spots" in the TG core and overheating of the insulation cause not only premature aging of high-voltage insulation of the stator and rotor windings, but also damage of the core package, due to which the TG must be removed for repair (Fig. 3). On average, increasing the temperature every 10 degrees reduces the duration of insulation aging by half [7].

Figure 3 – Burnout of TG stator winding, which led to damage to the core package [6]

Mechanical deformation of the core is mainly caused by the lack of sufficiently reliable fastening of the stator core plates or the core segments deformation in large machines with a segmented core design. Cores made of several segments (usually from two to eight) can be damaged in the area of their connection due to the movement of a core sections (Fig. 4). In addition, the metal components, which for some reason got into the air gap, can also mechanically damage the core of the TG. Lack of sufficient compression of the core in the presence of large magnetic forces can cause relative displacement of the plates and damage of the winding insulation by abrasion, which will lead to a short circuit and the appearance of an electric arc [6].

Figure 4 – The stator core end damage [6]

Insufficient strength or incorrect installation of pressure fingers of turbogenerators. The main reason for the mass occurrence of steel defects in the stator cores of turbogenerators type TVV-320-2 is the lack of reliability and strength of the pressure fingers (Fig. 5). The same reason for the insufficient level of reliability is observed on turbogenerators such type as TVV-1000-2. The margin of safety in the pressure fingers only from the action of static pressure of the press is only 14% [8]. This defect in the manufacture of the core is usually detected visually, as it leads to plastic deformation and/or displacement of the fingers from the initial position. Such damage leads to breakage of the glued packages of the stator core, tooth sheets and wear of the ventilation spacers of the turbogenerators.

Damage of the studs and breakage of the coupling prisms of turbogenerators. During of turbogenerators work or their repair damages of studs and breaks of coupling prisms of a stator can take place (fig. 5). The process of the coupling prisms damage leads to significant material and financial losses. The main causes of damage are increased vibration, cyclic thermomechanical stresses under variable load modes and the phenomenon of metal fatigue on the heads of coupling prisms [9].

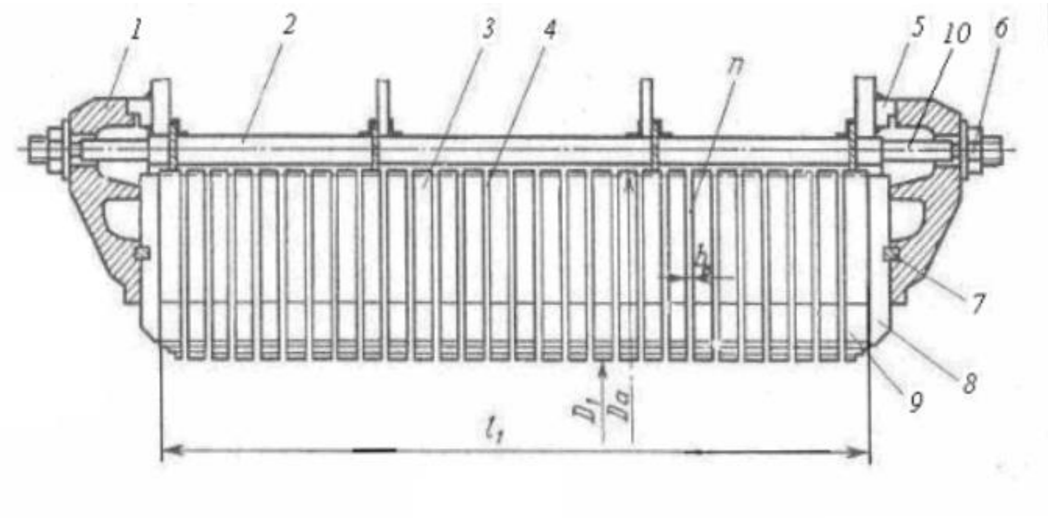

Figure 5 – The design of the TG stator core with a capacity of 300 MW [9]. Numbers indicated: 1 – pressure plate; 2 – clamping prism; 3 – active steel package; 4 – ventilation duct; 5 – support ring; 6 – nut; 7 – ring key; 8 – pressure finger; 9 – stepped extreme packages; 10 – pin of the coupling prism.

Conclusions. The article analyzes the impact of the turbogenerator damages on the reliability of its operation. To avoid the development of such injuries, it is necessary to constantly monitor the technical condition of TG using diagnostic methods.

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